

Technical Paper

Development of an ASTM E 84 Class 1 Fire and Smoke Vinyl Ester Resin

Abstract

A unique new fire retardant vinyl ester resin that meets ASTM E 84 Class 1 flame spread and **smoke** rating has been developed. This paper will review resin properties including specific details on the cast resin properties, fire testing results, laminate physical properties, corrosion resistance and end uses.

Introduction

A highly brominated bisphenol-A epoxy based vinyl ester (Vipel® K022-AAA-00) meets the current ASTM E84 Class 1 rating for flame spread and **smoke** development. In order to meet the class 1 criteria the laminate must have a flame spread of 25 or less and a smoke development of 450 or less. The unique aspect is that the ASTM E84 Class 1 smoke requirement is met. This paper reviews the cast mechanical properties, ASTM E 84 test results, UL 94 results, mechanical properties at elevated temperatures, corrosion resistant data, and some applications for this resin. Cast properties of a typical general-purpose fire retardant resin and a non-fire retardant bisphenol-A epoxy vinyl ester resin are included for reference.

Experimental

1) Casting Preparation

Resins were catalyzed and poured between two 63.5 mm/¼ inch thick glass plates. A 0.130 inch/33 mm thick thermoplastic gasket is used as a spacer so that the final cured casting is 0.125 inch/32 mm thick. Table #1 details how the Vipel® K022-AAA-00 casting was catalyzed and cured.

2) Laminate Preparation

Table #2 describes how the Vipel® K022-AAA-00 laminates were prepared. This includes the promoter catalyst, reinforcement used in the construction, glass content, thickness and the post cure schedule.

3) Mechanical Properties

Woven roving /chopped strand laminates were prepared with the Vipel® K022-AAA-00 and an alternative product (competitive brominated bisphenol-A epoxy fire retardant vinyl ester resin) according to table #3.

4) Corrosion Resistance

a) Test Coupons

Laminate corrosion of Vipel® K022-AAA-00 and an alternative product were compared. Test coupons of Vipel® K022-AAA-00 and an alternative product were produced according to ASTM C 581. Solutions were changed every month except for the sodium hypochlorite which was changed every two weeks. In caustic environments, a polyester veil was used instead of a glass veil.

Details of the promoter, catalyst, laminate construction and the post cure schedule are given in table # 4.

b) Chemical Environments

The resins were tested in nine environments. The concentration of each chemical and the temperatures are listed in table # 5.

Results

Cast Properties

The cast resin mechanical properties of Vipel® K022-AAA-00 are listed in table #6. The mechanical values of a typical general-purpose fire retardant and a non-fire retardant vinyl ester are included for reference.

Fire and Smoke

ASTM E 84 and UL 94 test results for Vipel® K022-AAA-00 laminates are listed in Table #7

Mechanical Properties

Flexural properties at elevated temperatures of Vipel® K022-AAA-00 and an alternative product are shown in Table #8 and Table #9 respectively.

Figure #1 compares the flexural strength of the of the Vipel® K022-AAA-00 and alternative product in graphic form.

Figure #2 compares the flexural modulus of the of the Vipel® K022-AAA-00 and alternative product in graphic form.

Corrosion Resistance

The mechanical properties are plotted with time in each of the chemical environments for Vipel® K022-AAA-00 and an alternative product.

Mechanical strength is the average of the retention of flexural strength and retention of flexural modulus:

$$\text{Mechanical strength} = \frac{\text{Retention flexural strength} + \text{Retention flexural modulus}}{2}$$

Figure # 3: Retention of mechanical strength after 1 year of exposure in 5% nitric acid at 100°C/212°F

Figure # 4: Retention of mechanical strength after 1 year of exposure in 10% sulphuric acid at 100°C/212°F

Figure # 5: Retention of mechanical strength after 1 year of exposure in 15% hydrochloric acid at 100°C/212°F

Figure # 6: Retention of mechanical strength after 1 year of exposure in 100% demineralised water at 100°C/212°F

Figure # 7: Retention of mechanical strength after 1 year of exposure in 5.25% sodium hypochlorite at 50°C/122°F

Figure # 8: Retention of mechanical strength after 1 year of exposure in 5% sodium hydroxide at 100°C/212°F

Figure # 9: Retention of mechanical strength after 1 year of exposure in 100% toluene at 20°C/68°F

Figure # 10: Retention of mechanical strength after 1 year of exposure in 100% aniline at 20°C/68°F

Figure # 11: Retention of mechanical strength after 1 year of exposure in 100% methanol at 20°C/68°F

Application

Vipel® K022-AAA-00 vinyl ester resin is now being used in theme parks such as the “Men in Black” ride at Universal Studios in Orlando, FL. Vipel® K022-AAA-00 was used to manufacture the ferocious giant alien that won the “Peoples Choice Award” at the CFA conference in Las Vegas in September 2000. The reason that Vipel® K022-AAA-00 was chosen for this theme park is that the heat distortion and elongation were higher than typical general-purpose fire retardant resins. (Fire retardant properties were required for the theme park).

Also Vipel® K022-AAA-00 has been used to manufacture ventilation fans for chemical plants, pulp and paper mills and mines because of the combination of fire, smoke and corrosion properties.

Conclusion

- 1) The cast mechanical properties of the fire retardant and non-fire retardant version of Vipel® K022-AAA-00 resins are similar. The elongation and heat distortion properties of Vipel® K022-AAA-00 are higher than typical general-purpose fire retardant resins.
- 2) Vipel® K022-AAA-00 meets the ASTM E 84 Class 1 fire and smoke requirements.
- 3) Vipel® K022-AAA-00 meets UL 94 HB, 5V and V-0 requirements.
- 4) The elevated temperature mechanical properties of both Vipel® K022-AAA-00 and an alternative product begin to significantly decrease above 105°C/221°F.
- 5) The corrosion resistant properties of Vipel® K022-AAA-00 laminates are similar to the corrosion resistant properties of an alternative product.
- 6) The unique combination of good flame and smoke resistant properties combine With the inherently good mechanical properties contribute to Vipel® K022-AAA-00 being an excellent resin for these and many more fire retardant applications where fire and smoke resistance are required.

TABLE #1

CURE SYSTEM AND POST CURE SCHEDULE FOR PREPARATION OF CASTING

CATALYST AND CURE SCHEDULE	QUANTITY AND TIME
Catalyst system	
Benzoyl Peroxide (BPO), %	1
Cure schedule	
60°C/160°F, hours	4
93°C/200°F, hours	1
116°C/240°F, hours	1
138°C/280°F, hours	2

TABLE #2

CURE SYSTEM, CONSTRUCTION AND POSTCURE SCHEDULE FOR ASTM E 84 and UL 94 TESTING

Promoter system	0.1% Cobalt 12% solution
Catalyst system	1.25% MEKP (9% active oxygen)
Laminate build-up	2 plies of 2 ounce chopped glass strand mat
Glass content, %	30-32
Thickness, mm/inches	2.4/0.095
Postcure	hrs at 100°C/212°F

TABLE #3

CURE AND POSTCURE SCHEDULE FOR MECHANICAL TESTING

Resins	HBVE
Promoter system	0.33% Co* 6% solution
Catalyst system	2% MEKP (9% active oxygen)
Laminate Construction	v**/csm***/csm/W r****/ csm/wr/csm
Postcure	3 hrs at 100°C/212°F

- * Co - Cobalt
- ** v - glass veil
- *** csm - 1.5 ounce chopped glass strand mat
- **** wr - 24 ounce glass woven roving

TABLE #4

CURE AND POSTCURE SCHEDULE FOR CORROSION TESTING

Promoter system	0.33% Co* 6% solution
Catalyst system	2% MEKP (9% active oxygen)
Laminate Construction	2 plies of glass veil and 2 plies of 1.5 ounce chopped strand glass mat
Postcure	3 hrs at 100°C/212°F

* Co - Cobalt

TABLE #5

CHEMICAL RESISTANCE ENVIRONMENTS

CHEMICAL	CONCENTRATION	TEMPERATURE
Nitric acid	5%	100°C/212°F
Sulphuric acid	10%	100°C/212°F
Hydrochloric acid	15%	100°C/212°F
Demineralised water	100%	100°C/212°F
Sodium hypochlorite	5.25%	50°C/122°F
Sodium hydroxide	5%	100°C/212°F
Methanol	100%	20°C/68°F
Toluene	100%	20°C/68°F
Aniline	100%	20°C/68°F

TABLE #6

MECHANICAL PROPERTIES OF CASTINGS

Mechanical Properties	General Purpose Fire Retardant	Non-Fire Retardant Vinyl ester	HBVE
Tensile strength, psi	10,700	13,800	11,600
Tensile modulus, psi	580,000	540,000	490,000
Elongation, %	2.2	4.6	4
Flexural strength, psi	15,400	22,000	21,300
Flexural modulus, psi	590,000	570,000	550,000
Heat Distortion, °C/°F	90/194	112/234	119/246
Barcol Hardness	45	40	41

TABLE #7

ASTM E 84 AND UL 94 TEST RESULTS

TEST		RESULTS
ASTM E 84		
Flame spread		20
Smoke development		450
UL 94		
	HB	PASS
	5V	PASS
	V-0	PASS

TABLE #8

FLEXURAL PROPERTIES OF Vipel® K022-AAA-00 AT ELEVATED TEMPERATURES

Property	Glass Content %	20°C/68°F	20°C/68°F	90°C/194°F	105°C/221°F	120°C/248°F
Flexural Strength, psi	34	25,300	25,300	25,300	17,400	5,100
Flexural Modulus, Psi x 106	34	1.2	1.2	1.2	0.7	0.45

TABLE #9

FLEXURAL PROPERTIES OF AN ALTERNATIVE PRODUCT AT ELEVATED TEMPERATURES

Property	Glass Content %	20°C/68°F	20°C/68°F	90°C/194°F	105°C/221°F	120°C/248°F
Flexural Strength, psi	33	24,700	23,200	24,700	21,800	6,500
Flexural Modulus, Psi x 106	33	1.2	1.1	0.99	0.81	0.45



